UNITED STATES MARINE CORPS

LESSON PLAN

LAPSE RATES

INTRODUCTION:

1. Gain Attention. Why are the windward side of the mountains moist and wet and the leeward side dry and warm? California is extensively covered with ripe green shrubbery, trees, and plants, while eastern Rocky foothills are warm and dry.

2. Overview. The purpose of this period of instruction is familiarize the student with the rates at which temperature decreases and/or increases with height throughout the tropopause, as well as, how it affects the weather.

3. Introduce Learning Objectives.

   a. Terminal Learning Objective. With the aid of references, define and discuss the fundamental concept of the various types of lapse rates and how they affect weather conditions.

   b. Enabling Learning Objective(s). With the aid of the reference(s), complete the following tasks:

      (1) State and define the four different types of lapse rates.

      (2) Define an inversion and state the different types of inversions.

4. Method/Media. This period of instruction will be taught using the lecture method with aid of QMMCBT-001 “Introduction to the Dynamics of the Atmosphere”.

5. Evaluation. The student(s) shall be evaluated by using the practical application method by completing related exercises and by applying learned knowledge to the Skew-T, Log P Diagram.

TRANSITION. Recall that the vertical temperature profile in the troposphere decreases with height. The question becomes how fast or how slow does the temperature change and what does this mean? This class will further discuss the significance moisture plays in the adiabatic process.

BODY:

1. Adiabatic Temperature Changes.

a. The adiabatic process deals with the changing temperature of a parcel of air due to rising or sinking the air. An adiabatic process assumes no heat, mass or momentum pass across the air parcel boundary.

b. An example of adiabatic temperature changes would include one feeling the cooling effect of propellant gas expanding as hair spray or spray deodorant is applied. Another example would be a tire inflation. As one pumps air into the tire, the tire expands and the air within the tire cools. When air is let out of the tire, the tire deflates (is compressed) and the air inside of the tire warms. No exchange of heat of the air within the tire has been made with the air outside of the tire.

c. The vertical temperature gradient is the rate of change in temperature with height. It is symbolized by the Greek letter Gamma (γ). A lapse rate can be mathematically expressed as the following:

$\gamma = -\frac{\Delta T}{\Delta z}$ ~~where~~ γ is the lapse rate, ΔT equals the temperature of the upper layer minus the temperature of the lower layer, and Δz equals the height of the upper layer minus the height of the lower layer. The units are measured in °C/km.

TRANSITION. Now that we have reviewed the concept of adiabatic temperature change, we can discuss adiabatic lapse rates.

2. Dry Adiabatic Lapse Rate.

a. Any time of parcel of air moves upward in the atmosphere, it will pass through regions of successively lower pressure. Because of this, ascending air expands and cools adiabatically. Unsaturated air cools at a constant rate of 10°C for every 1000 meters of ascent (5.5°F per 1000 feet). On the other hand, descending air falls through increasing pressure and will compress and warm 10°C for every 1000 meters. This rate of heating or cooling is called the *dry adiabatic lapse rate (DALR)* and is only associated with vertically moving unsaturated air. When the temperature decreases with height is known as a positive lapse rate.

b. The dry adiabatic lapse rate can be mathematically calculated or visualized by using the dry adiabats on the Skew-T, Log P Diagram.

(1) By using mathematical calculations, one is able to determine the temperature at a given height by subtracting the appropriate values per interval. For example, if the surface temperature is 35°C and one needs to calculate the temperature of a dry parcel of air at 2km, 20°C would be subtracted (10°C per every 1000 meters) from 35°C for a 2km temperature of 15°C. Another example would be if the surface temperature was 40°C and one needs to calculate the temperature of dry air at 500 meters, 5°C would be subtracted (10°C per every 1000

meters = 1°C per every 100 meters) for at 500 meter temperature of 35°C.

(2) Dry adiabats on the Skew-T are lines of constant potential temperature and are represented by slightly curved, solid brown lines sloping from lower right to upper left on the chart. Dry adiabats are printed at a 2°C interval and labeled every 10°C.

TRANSITION. If a parcel of air rises high enough, it will eventually cool to its dew-point. At this point condensation begins. The altitude at which a parcel reaches saturation and condensation occurs is called the lifted condensation level. At this level something happens.

Instructor Note: Ask the students what happens to the parcel of air after it reaches the point of saturation.

3. Moist Adiabatic Lapse Rate.

a. At the lifting condensation level (lcl), the latent heat that was absorbed by the water vapor when it was evaporated is liberated. The parcel will continue to rise adiabatically, but the latent heat release slows the rate of cooling. This slower rate of cooling is called the *moist adiabatic lapse rate* (MALR). The rate of cooling is reduced because the release of latent heat partially offsets the cooling due to expansion (this heat was originally stored as latent heat of vaporization).

b. The amount of latent heat released depends on pressure and the quantity of moisture present in the atmosphere, generally between 0 and 4 percent, but averages about 6°C (3.3°F per 1,000 feet) per kilometer. Because the MALR depends on the amount of moisture present in the air, it can range from 5°C per 1000 meters for air containing a high moisture content to 9°C per 1000 meters for air containing a low moisture content.

c. The image provided below demonstrates the role of adiabatic cooling in cloud formation. Note that from the surface up to the LCL, the air cools faster and at the DALR. The MALR begins at the point of saturation, after the parcel reaches the LCL.

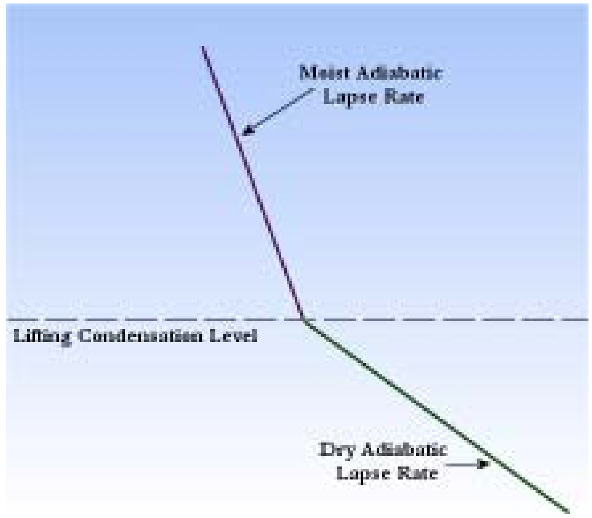

Figure 1 – Dry and Moist Adiabatic Lapse Rate.

TRANSITION. After discussing the rates of which unsaturated air or saturated air will rise or fall adiabatically, it is important to discuss the actual temperature of the parcel of air.

4. Environmental Lapse Rate.

a. The rate at which temperature decreases throughout the atmosphere is variable, especially within the lowest few hundred feet of the troposphere. The average lapse rate is 6.5°C per 1000 meters (3.3°F per 1000 feet) and in known as the *environmental lapse rate*. This lapse rate is highly variable and can vary throughout the day with fluctuations of weather, it may vary seasonally, and from place to place.

b. The environmental lapse rate for a column of air is determined by measuring the air temperature within that column. This is done by the use of radiosondes (rawinsondes) which take temperature readings throughout the atmosphere, as well as other atmospheric elements, at various elevations. A graph is then plotted, Skew-T, Log P Diagram, to succeed in plotting a temperature profile for that measured column of air. Many radiosondes are launched throughout the United States, and other countries, and the data is then compiled for further atmospheric analyzation.

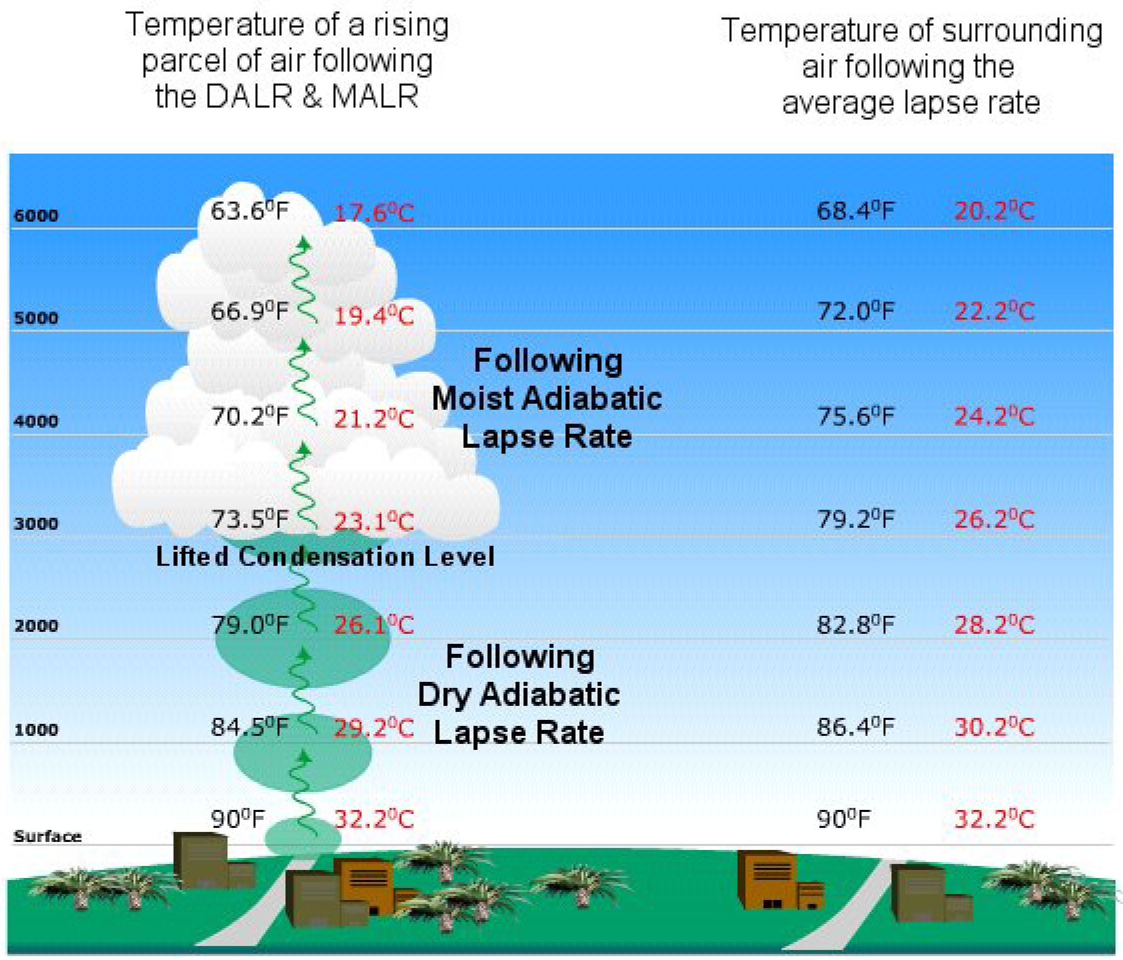

Figure 1 – Parcel of air ascending into the atmosphere, first at the dry adiabatic lapse rate, then at the moist adiabatic lapse rate. Compare to the temperatures on the left that are rising at the standard lapse rate.

4. Dew-Point Lapse Rate.

a. Like temperature, the dew point also decreases with height because of decreasing pressure.

b. As a rule of thumb, the dew point decreases approximately 2°C per 1000 meters.

OPPORTUNITY FOR QUESTIONS:

1. Questions from the Class. At this time are there any questions about the material that has just been presented?

2. Questions to the Class. At this time there will be no questions for the students.

SUMMARY: This class provided a fundamental overview of the rates at which air decreases throughout the atmosphere and the effect it has on cloud formation. It also provided a review of the adiabatic temperature process in which ultimately defines the lapse rates.

REFERENCE:

The Atmosphere, An Introduction to Meteorology. Frederick K. Lutgens and Edward J. Tarbuck.

Physical Geography, A landscape Appreciation. Tom L. McKnight and Darrel Hess.